Farmers Wanted | A Model For Predicting Climate Change Impacts on Agricultural Land Suitability

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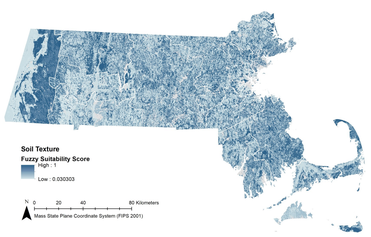
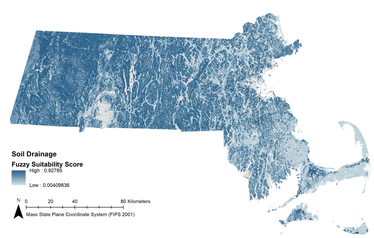
Introduction

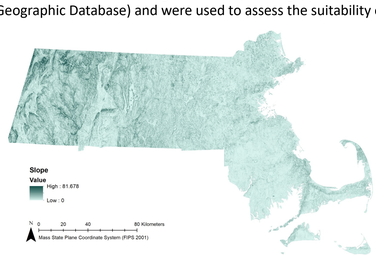
Farmers in arid regions of the US that grow large portions of US produce face increasing drought and uncertainty due to climate change. As a result, vegetable production may shift to other areas of the country. States that have lower threats of water shortages compared to arid regions of the United States could benefit economically from a shift to high-value vegetable crops. Massachusetts vegetable production increased from 2007 to 2012, but many of these crops are sensitive to changing temperatures and precipitation[1]. Massachusetts farmers are aware that the climate is changing and that they will need to adapt, but do not have sufficient data to assess how their own farmland could be affected. This project developed a model to assess the current and predicted suitability of land in Massachusetts for diversified vegetable production using historical climate data and a predicted climate change scenario. The model evaluates the predicted change in land suitability by county to determine which areas might remain suitable for vegetable production and which could be at risk for decreased production in the future.

Data

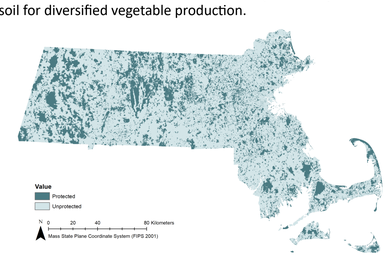




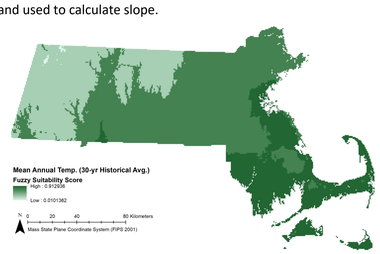
Soil characteristics including soil texture, drainage, pH, organic matter, and depth were obtained from SSURGO (Soil Survey Geographic Database) and were used to assess the suitability of the soil for diversified vegetable production.

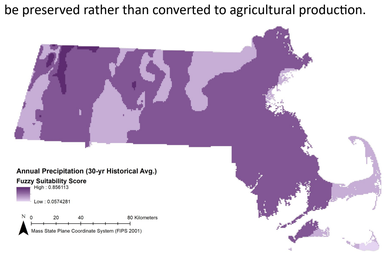


Elevation data were downloaded from the US Geological Survey and used to calculate slope.

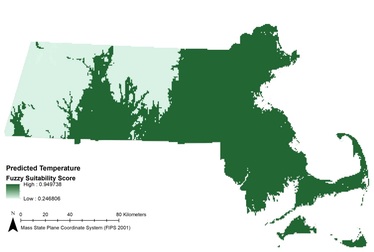


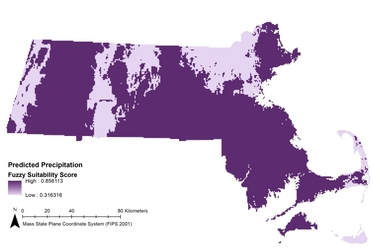
Land cover data was used to identify protected lands which should be preserved rather than converted to agricultural production.



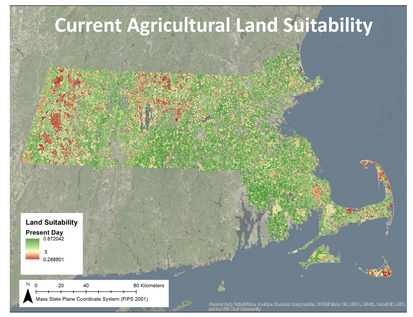


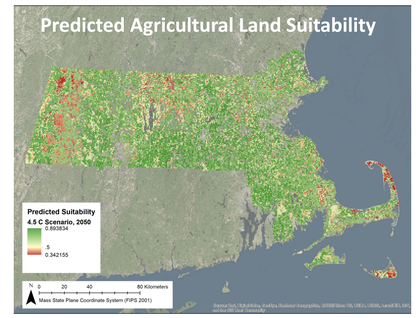
30-year historical averages for precipitation and mean annual temperature provided climate data to assess current land suitability.

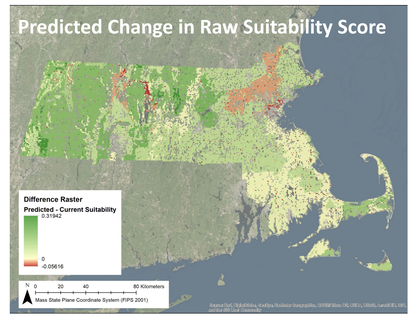




Predictions for temperature and precipitation in 2050 for a 4.5°C global temperature rise scenario were used to predict future land suitability.



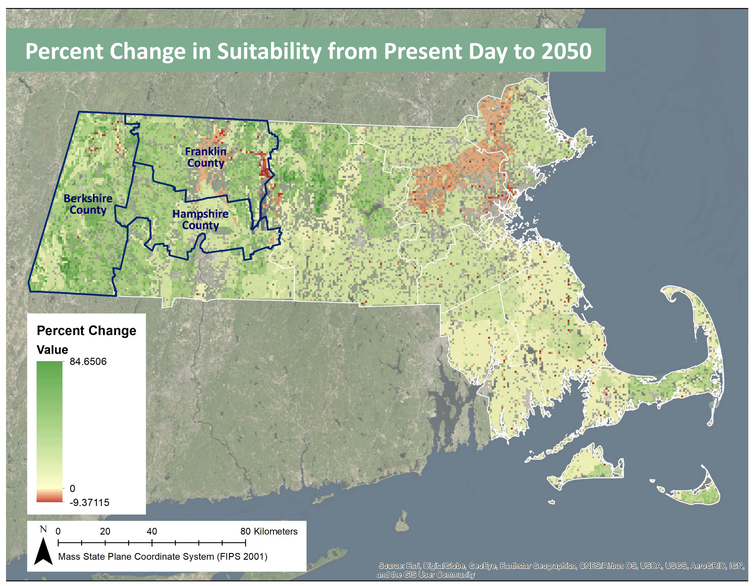




Category	Weight
Land Cover	23.0%
Temperature	15.7%
Precipitation	15.7%
Slope	10.6%
Soils Characteristics	*34.9%*
Texture	12.0%
Depth	8.4%
Drainage	5.8%
Organic Matter	4.8%
pH	3.9%

Methodology

1. **Prepared layers for analysis.** Joined attribute tables for soil data, clipped all layers to state boundaries, and rasterized if necessary.
2. **Reclassified layers** based on suitability characteristics as defined by FAO (Food and Agriculture Organization) crop requirements and land suitability analysis guidelines.
3. **Converted reclassified layers to fuzzy membership layers**, indicating that larger numbers are more likely to be suitable. Fuzzy logic helps account for uncertainty in the data.
4. **Performed suitability analysis using weighted overlay**. Weights were determined using FAO guidelines and the AHP (Analytic Hierarchy Process) method.
5. **Created difference and percent change raster layers** using the Map Algebra tool.
6. **Used Zonal Statistics** to assess the predicted change in suitability in each Massachusetts county.



Results and Conclusions

County	Suitability Score		Mean Difference	
	Current	2050	Raw	%Change
1. Berkshire	0.539	0.602	0.063	12.82
2. Hampshire	0.624	0.678	0.054	9.28
3. Franklin	0.590	0.639	0.050	9.27
4. Hampden	0.637	0.691	0.053	8.88
5. Nantucket	0.445	0.487	0.034	8.80
6. Worcester	0.630	0.673	0.043	7.73
7. Norfolk	0.671	0.696	0.026	4.11
8. Barnstable	0.575	0.596	0.022	4.07
9. Essex	0.647	0.665	0.018	3.12
10. Middlesex	0.645	0.660	0.016	2.63
11. Dukes	0.641	0.655	0.014	2.50
12. Plymouth	0.644	0.654	0.010	1.74
13. Briston	0.696	0.705	0.009	1.37
14. Suffolk	0.689	0.702	0.008	1.28

Overall, the model predicted slight to moderate increases in land suitability for vegetable production on a county basis in Massachusetts. The largest increases were in counties in western Massachusetts, which appears to be due to a predicted increase in precipitation. The three counties with the highest percent change in land suitability, Berkshire, Hampshire, and Franklin, are outlined in navy (bottom center map). Historical mean temperature and precipitation for Massachusetts were generally low in comparison to the FAO-suggested levels for cultivation; farmers who employ sufficient climate adaptation strategies could take advantage of higher temperatures and rainfall. However, this model is subject to limitations:

- **There is a high degree of uncertainty in the data.** Future climate scenarios are not guaranteed and human activity can cause large variations in climate outcomes. Large cell sizes may not account for microclimates caused by elevation and land cover. Additionally, soils data is highly variable, and there may be multiple soil types in a single polygon.
- **Different vegetables require different growing conditions.** Layers were classified based on average crop needs. This is useful to farmers with diversified vegetable growing operations, but may not be universally applicable.
- **The model does not account for acute climate related stressors**. This model considers only mean temperature and precipitation. It does not include frequency of extreme weather events or changes in pest and disease occurrence.

In the 4.5°C scenario used in this model, the future of vegetable production in Massachusetts appears promising. However, the model should be repeated with climate data for multiple temperature scenarios and from multiple sources. It could be adapted to more specific crop requirements for farmers with varying types of farming operations. Lastly, acute stressors should be examined, either in future iterations of this model or in others, in order to help farmers make decisions about potential climate adaption strategies. Continued study of the impacts of climate change will be vital to the success of Massachusetts's agricultural economy.

Sources

[1]Census of Agriculture - State Data, 2012; published by USDA.
SSURGO, 1982, US Geological Service; published by NRCS.
Mean Annual Temperature (30-yr Normals), 2010; published by PRISM Climate Group,
Annual Precipitation (30-yr Normals), 2010; published by PRISM Climate Group.
2050 Mean Annual Temperature (CC 45), 2014; published by WorldClim.
2050 Annual Precipitation (CC 45), 2014; published by WorldClim
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1/3 arc-second Digital Elevation Model (DEM), Updated 2018; published by USGS.
Protected and Recreational Open Space, May 2017; published by MassGIS

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